GAS EXCHANGE TRANSIENT BUFFERING SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority to U.S. Provisional Patent Application No. 62/992,618, filed Mar. 20, 2020, which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Gas exchange measurement systems, such as systems for measuring plant photosynthesis and transpiration rates, can be categorized as open or closed systems. For open systems, a leaf or plant sample may be enclosed in a sample chamber, and an air stream is passed continuously through the chamber. CO_2 and H_2O concentrations of chamber influent and effluent are measured, and the difference between influent and effluent concentration is calculated. (Throughout this document the term "concentration" refers to mole fraction of a gas in natural or synthetic moist air, or mole fraction in natural or synthetic dry air ("dry mole fraction") where such is specified.) This difference may be used, along with the mass flow rate, to calculate photosynthesis (CO_2) and transpiration (H_2O) rates. For closed systems, the leaf or plant is enclosed in a chamber that is not supplied with fresh air. The concentrations of CO_2 and H_2O are continuously monitored within the chamber. The rate of change of this concentration, along with the chamber volume, may be used to calculate photosynthesis (CO_2) and transpiration (H_2O) rates.

[0003] Gas exchange systems are often used outdoors in plant canopies where the magnitude of ambient gas concentrations may be highly variable, and the rate of change may be significant. For example, water and carbon-dioxide concentrations in a canopy vary radically due to active plant transpiration and photosynthesis, and passive physical phenomena such as stratification and wind. Often, the conditions at which gas exchange measurements are taken outdoors are meant to mimic ambient conditions. These ambient conditions are most easily replicated in open gas exchange systems by using ambient air as the fresh air supply. A typical open gas exchange system can measure reasonable exchange rates in the presence of slow changes in ambient airstream water vapor or carbon dioxide concentrations. However, sufficiently fast transients can be misconstrued by the measurement system as gas exchange and introduce measurement errors.

[0004] In an example gas exchange system, an airstream passes over a sensor that measures incoming water vapor content (reference sensor), after which it passes through a cuvette containing biological material that adds or removes water vapor to the airstream, and finally passes over a second sensor (sample sensor) to measure outgoing water vapor content. Measurement errors in this system result if changes in the incoming water vapor content occur on a similar time-scale to that of the measurement. Sufficiently fast transients in water vapor concentrations reach the two sensors at different times, and a time lag between the reference and sample sensors results. Time lags result in the erroneously perceived introduction/removal of water vapor from the cuvette as calculated from the instantaneous difference between the reference and sample sensors. Moreover, transpirations rates become more difficult to interpret under transient ambient water vapor concentrations, and a nearly constant concentration during the measurement is most often desired.

[0005] Thus, there is a need for improved gas exchange analysis systems and methods for samples that may generate or remove water content from an airstream or gas flow.

SUMMARY

[0006] The present disclosure provides systems and method for reducing or minimizing the impact of ambient water vapor transients on measurements in a gas exchange measurement system. More generally, embodiments dampen or smooth-out fast transients in ambient air supply, and allow for controlling the rate at which transients which are propagated through the measurement system, maintaining measurement performance while approximating ambient conditions, by buffering the in-coming air in the gas exchange measurement system. Advantageously, the incoming water vapor content is not controlled to a set humidity, but rather incoming rapid transients are smoothed such that i) rapid incoming transients do not create an erroneous measurement artifact, and ii) nearly constant conditions are maintained during a given measurement.

[0007] According to an embodiment, a gas exchange analysis system is provided that includes a water vapor buffering component, the water vapor buffering component including a material configured to buffer water vapor in a flow of a gas, whereby fluctuations in the water vapor content in the flow of the gas are slowed for components downstream from the water vapor buffering component in the gas exchange system, wherein the components downstream of the water vapor buffering component include: a first water vapor sensor configured to receive the flow of the gas from the water vapor buffering component and configured to measure a first concentration of water vapor in the gas; a sample chamber configured to receive the gas exiting the first water vapor sensor and to hold a sample capable of adding or removing water vapor from the gas; and a second water vapor sensor configured to measure a second concentration of water vapor in the gas exiting the sample chamber.

[0008] In another embodiment, a gas analysis system is provided that includes a first water vapor sensor configured to receive a flow of the gas from a first gas flow line and configured to measure a first concentration of water vapor in the gas received from the first gas flow line, a sample chamber configured to hold a sample capable of adding or removing water from the gas, a second water vapor sensor configured to measure a second concentration of water vapor in the gas exiting the sample chamber, and a water buffering component in the first gas flow line before the first water vapor sensor, the water buffering component including a material configured to buffer water vapor content in the flow of the gas, whereby fluctuations in water vapor content in the flow of the gas are slowed for components downstream from the water buffering component in the gas exchange system. The system may include a gas source configured to provide the flow of the gas.

[0009] In certain aspects, the material absorbs or desorbs water in the presence of a water concentration gradient. In certain aspects, the material includes a Nafion® structure. Nafion is a sulfonated tetrafluoroethylene based fluoropolymer-copolymer developed by DuPont. In certain aspects, the structure is selected from the group consisting of a bead,